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Patent Application

Inventor(s):   Bryan Hubbard and Pierre Leroux

Title: WAFER TARGET DESIGN AND METHOD FOR DETERMINING CENTROID OF WAFER TARGET

The Commissioner of Patents and Trademarks
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Transmittal of a Patent Application
(Under 37 CFR §1.53)

Transmitted herewith is the above identified patent application, including:

  X   Specification, claims and abstract, totaling   35   pages.
_____ Formal drawings, totaling   _____   pages.
  X   Informal drawings, totaling   8   pages.
  X   Declaration and Power of Attorney.
_____ Information Disclosure statement.
_____ Form 1449
  X   Assignment(s)
  X   Assignment Recordation Form (duplicate)
_____ Preliminary Amendment

FEES DUE

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CLAIMS					
	NO. OF CLAIMS		EXTRA CLAIMS	RATE	FEES
Basic Application Fee					$690.00
Total Claims	22	Minus 20=	2	X $18 =	$36.00
Independent Claims	4	Minus 3=	1	X $78=	$78.00
If multiple dependent claims are presented, add $260.00					$0.00
Add Assignment Recording Fee of $40.00 If Assignment document is enclosed					$40.00
TOTAL APPLICATION FEE DUE					$844.00

                                                    rev. 11/98 wmh

PAYMENT OF FEES

The full fee due in connection with this communication is provided as follows:

1.   Not enclosed

         [ ]   No filing fee is to be paid at this time.

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      This application is filed pursuant to 37 C.F.R. § 1.53 in the name of the above-identified Inventor(s).
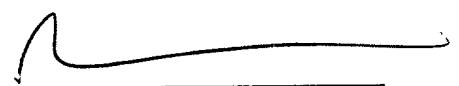
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Respectfully submitted,

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        rev. 11/98 wmh

VLSI 3234

UNITED STATES PATENT APPLICATION

FOR

WAFER TARGET DESIGN AND METHOD FOR DETERMINING

CENTROID OF WAFER TARGET

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WAFER TARGET DESIGN AND METHOD FOR DETERMINING CENTROID
OF WAFER TARGET

TECHNICAL FIELD

The present claimed invention relates to the field of semiconductor

5   wafer fabrication. More specifically, the present claimed invention relates to

a target design used for aligning a wafer, and a method for determining a

centroid of a target.

BACKGROUND ART

10   Integrated circuits (ICs) are fabricated en masse on silicon wafers

using well-known photolithography, etching, deposition, and polishing

techniques. These techniques are used to define the size and shape of

components and interconnects within a given layer of material deposited on

a wafer. The IC is essentially built-up using a multitude of interconnecting

15   layers, one formed on top of another. Because the layers interconnect, a

need arises for ensuring that the patterns on adjacent layers of the wafer are

accurately formed. Conventional methods rely heavily on accurate

alignment of the wafer, using targets, to ensure accurate formation of circuit

patterns on the wafer.

20

Referring now to prior art Figure 1A, a detail view of a conventional

alignment target, formed in a wafer 100a is shown. Alignment target 104 is

shown in a cross-section view of a wafer, with its length running

perpendicular to the X-Z plane shown, to form a rectangular bar shape.

25   Layer of oxide 106 is located above a substrate 102. A trench in layer of

oxide 106 is filled with a material, e.g. tungsten, to form target 104. The

tungsten material is polished down, using Chemical Mechanical Polishing

(CMP) methods and apparatus, to leave just the tungsten material in the trench to act as target 104.

Due to the mechanical nature of the CMP method, apparatus and materials, the top surface 112 of target 104 can have residue buildup 110a in a corner of trench 104. The direction of pad rotation for the CMP operation is shown by direction arrow 111. Frequently, the residue buildup 110a cannot be removed from the trench 104. Hence, it becomes trapped under the subsequent layer of material 108, typically metal, deposited onto the wafer. A photoresist layer 116 is deposited on top of layer 108. A pattern is typically exposed on the photoresist layer 116.

However, to locate the pattern accurately, the target location is acquired by reading a reflected signal from the edges 114a and 114b formed by the concave surface 112 of the trench 104 in the wafer 100a. Unfortunately, the trapped residue 110a frequently creates an irregular surface 114a in the subsequent layer of material 108 deposited on it in an area proximate to the trapped residue 110a. The surface irregularity 114a subsequently skews the signal, reflected from the surface of layer 108, used to detect the center of the target. The skewed signal consequently misrepresents the actual location of the target on the wafer, thus mislocating subsequently created patterns, e.g. ICs, formed on the wafer. This mislocation can cause poor wafer yield or can cause subsequent product failures. Consequently, a need arises for an apparatus and a method that will accurately locate the target on a wafer regardless of the flatness of the target surface.

A recent development in conventional CMP operations is a change from ferrous nitrate material to potassium iodate material for the abrasive slurry. However, potassium iodate does not possess some of the benefits of ferrous nitrate. That is, while potassium iodate leaves less residue on the

5   target, it actually makes corners 110a and 110b of target 104 more asymmetric. Consequently, when using potassium iodate the asymmetry of surface 112, edges 110a and 110b, and edges 114a and 114b, would be worse than those created using ferrous nitrate polishing material.

10   Referring now to prior art Figure 1B, a graph showing a conventional return signal with a conventional minima used to determine a centroid of a wafer target is shown. Graph 100d has an ordinate of intensity of returned signal 120 and a location 122 of the wafer or target from where the signal is received. Specifically, area 134 of return signal 124 is associated with a

15   return signal that was reflected from surface 112 and corners 114a and 114b of metal layer 108 above target 104 in wafer 100a. Area 135 arises from a duplicate target formed in wafer, e.g. an unshown target that would be parallel to target 104 in prior art Figure 1A. Conventionally, a minima of the target is determined by a slope of the signal arising from non-flat surface and

20   corners 114a and 114b of metal layer 108 above target 104, as shown in prior art Figure 1A. However, slope 1 141 and slope 2 142 of return signal 124 are not symmetrical in prior art Figure 1B. This is due to the fact that reflected signal 124 from one edge, e.g. edge 114a, is different than the reflected signal from another edge, e.g. edge 114b, of the surface of the

25   layer of material 108 located above target 104. This unsymmetrical signal is due to the asymmetry between edges 114a and 114b, and due to the roughness of edge 114a. Again, this asymmetry is exacerbated by the new potassium iodate material used in the CMP process.

As a result of the poor quality of the return signal 124 from two targets, the location of the center of the individual targets, e.g. as determined by minima 1 (MIN 1) 131 and minima 2 (MIN 2) 132 is inaccurate.

5   Consequently, the centroid 108 of the target pattern, determined by location of the centers of the individual targets, is frequently mislocated. Given the close tolerances of conventional and future Integrated Circuit (IC) designs, the mislocation of the target is unacceptable. Consequently, a need arises for an apparatus and a method that will accurately locate the target on a

10   wafer regardless of the asymmetry of the target surface.

The width 113a of the target 104 formed in layer 106 using conventional methods and apparatus effectively becomes narrower on subsequent layer of material. Thus, in layer 108, a width 113b of target is

15   actually narrower than the original width 113a. For example, if width 113a is 4 microns (μ) then width 113 would be on the order of approximately 2μ. With a target this small, conventional stepper apparatus and software is frequently unable to even acquire the target. If the target cannot be acquired, then further processing steps may not be feasible, because the

20   stepper is essentially blind to the position of the wafer. Thus, the wafer becomes useless and is typically scrapped. Consequently, a need arises for a method and apparatus with increased target acquisition rate, using either a conventional or a modified target.

25   Because the conventional targets are designed to have relatively long and straight edges, the CMP operation can significantly affect the symmetry

and shape of the edges of the target. Additionally, because the conventional location method depends upon the reflected signal from the edges of the target, it is substantially dependent upon the condition of the edges of the target. Consequently, a need arises for a target design that is immune from

5   the asymmetry and non-flat surfaces likely to arise in conventional CMP processes.

In summary, a need arises for ensuring that patterns on adjacent layers of the wafer are accurately formed. To satisfy this need, a need arises

10   for an apparatus and a method that will accurately locate a target on a wafer regardless of the flatness of the target surface. Additionally, a need arises for an apparatus and a method that will accurately locate the target on a wafer regardless of the asymmetry of the target surface. Another need arises for a method and apparatus with an increased target acquisition rate, using

15   either a conventional or a modified target. Lastly, a need arises for a target design that is immune from the asymmetry and non-flat surfaces likely to arise in conventional CMP processes.

DISCLOSURE OF THE INVENTION

The present invention ensures accurate formation of patterns on adjacent layers of the wafer by providing accurate target location. Additionally, the present invention provides an apparatus and a method that

5   will accurately locate a target on a wafer regardless of the flatness of the target surface. Furthermore, the present invention provides an apparatus and a method that will accurately locate the target on a wafer regardless of the asymmetry of the target surface. The proposed apparatus and method has an increased target acquisition rate, using either a conventional or a

10   modified target. Finally, the present invention provides a target design is immune from the asymmetry and non-flat surfaces likely to arise in conventional CMP processes.

In one embodiment, the present invention provides a method for

15   determining the centroid of a wafer target. In one embodiment, the method comprises a series of steps in a stepper, starting with the step of receiving a wafer having a target set formed therein. Next, a signal is passed over the target shapes and over a material separating target shapes within the target set. The signal is reflected from the surface of the target shapes and from the

20   material separating the targets, and is subsequently detected by a sensor. A location of at least one maxima point of the return signal is identified. The maxima corresponds to a return signal reflected off of the material that separates the target shapes of the target set. Finally, a centroid is calculated as the median of the locations of the maxima points of the reflected signal

25   from the material area separating the targets. Because the present embodiment utilizes the maxima of the return signal from a material separating the targets, it avoids problems with the target edges that identify the return signal minima from the target surface, used by the prior art. This

embodiment is implemented by programming a stepper to read two virtual rectangle targets. The two virtual rectangle targets are implemented by instructing the stepper to read the four conventional rectangle targets as the side walls of the two virtual rectangle targets. Thus, where conventional

5   methods would not be able to acquire independent targets, the present invention increases target acquisition rate, using either a conventional or a modified target, by effectively constructing larger virtual targets from the smaller actual targets.

10   In another embodiment, the present invention recites a target pattern that is immune from the asymmetry and non-flat surfaces arising in conventional targets generated by conventional CMP operations. In particular, one embodiment of the present invention is a target pattern having a solid spine extending in one direction, and a plurality of fingers

15   coupled to the solid spine extending perpendicular to a lengthwise axis of the spine. Alternatively, the fingers can independently or dependently extend at different angles from the axis of said solid spine. The fingers have a gap between each other. Surrounding the target pattern is a background of appropriate gray scale shade. In one direction, the target pattern is a solid

20   shade, e.g. opaque, while the background is another gray scale shade, e.g. transparent. The spine of the present embodiment provides a strong return signal representing the centroid of the target pattern, while the narrow and unconnected ends of the fingers provide edges that are immune from asymmetry and non-flatness arising from a conventional CMP processes.

25

These and other objects and advantages of the present invention will no doubt become obvious to those of ordinary skill in the art after having

read the following detailed description of the preferred embodiments illustrated in the various drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

The accompanying drawings, which are incorporated in, and form part of, this specification, illustrate embodiments of the invention and, together with the description, serve to explain the principles of the invention. The

5   drawings referred to in this description should be understood as not being drawn to scale except as specifically noted.

PRIOR ART FIGURE 1A is a detail view of a conventional alignment target, formed in a wafer.

10

PRIOR ART FIGURE 1B is a graph showing a conventional return signal with a conventional minima used to determine a centroid of a wafer target.

15   FIGURE 2 is a block diagram of a stepper adapted to locate the centroid of a target in a wafer, in accordance with one embodiment of the present invention.

FIGURE 3A is a wafer with an alignment target formed therein, in

20   accordance with one embodiment of the present invention.

FIGURE 3B is the wafer of Figure 3A, in a cross-sectional view, in accordance with one embodiment of the present invention.

25   FIGURE 3C is a graph showing a signal with a maxima used to determine a centroid of a target, in accordance with one embodiment of the present invention.

FIGURE 4 is a flowchart of the steps performed to determine a centroid of a target in a wafer, in accordance with one embodiment of the present invention.

5   FIGURE 5A is a first configuration of a target pattern that is highly tolerant to asymmetry and non-flatness, in accordance with one embodiment of the present invention.

FIGURE 5B is a second configuration of a target pattern that is highly

10   tolerant to asymmetry and non-flatness, in accordance with one embodiment of the present invention.

FIGURE 5C is a wafer with a target having asymmetry and flatness immunity, in accordance with one embodiment of the present invention.

15

FIGURE 5D is the wafer of Figure 5C, in a cross-sectional view, in accordance with one embodiment of the present invention.

FIGURE 5E is a graph showing a return signal from a wafer target

20   having a pattern such as the one shown in Figure 5C, in accordance with one embodiment of the present invention.

BEST MODE FOR CARRYING OUT THE INVENTION

Reference will now be made in detail to the preferred embodiments of the invention, examples of which are illustrated in the accompanying drawings. While the invention will be described in conjunction with the

5   preferred embodiments, it will be understood that they are not intended to limit the invention to these embodiments. On the contrary, the invention is intended to cover alternatives, modifications and equivalents, which may be included within the spirit and scope of the invention as defined by the appended claims. Furthermore, in the following detailed description of the

10   present invention, numerous specific details are set forth in order to provide a thorough understanding of the present invention. However, it will be obvious to one of ordinary skill in the art that the present invention can be practiced without these specific details. In other instances, well-known methods, procedures, components, and materials have not been described

15   in detail so as not to unnecessarily obscure aspects of the present invention.

Some portions of the detailed descriptions which follow, e.g. the processes, are presented in terms of procedures, logic blocks, processing, and other symbolic representations of operations for fabricating patterned

20   layers, e.g. ICs, on a wafer. These descriptions and representations are the means used by those skilled in the art of wafer fabrication to most effectively convey the substance of their work to others skilled in the art. A procedure, logic block, process, etc., is herein, and generally, conceived to be a self-consistent sequence of steps or instructions leading to a desired result. The

25   steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these physical manipulations take the form of applying material, removing material, or changing the state or structure of a material on a wafer by chemical, optical, and mechanical means.

It should be borne in mind, however, that all of these terms are to be interpreted as referencing physical manipulations and quantities and are merely convenient labels and are to be interpreted further in view of terms

5   commonly used in the art. Unless specifically stated otherwise as apparent from the following discussions, it is understood that throughout discussions of the present invention, terms such as or "receiving," "passing," "identifying," "determining," or the like, refer to the action and processes of fabricating material and patterns on a wafer from a reticle.

10

Referring now to Figure 2, a block diagram of a stepper adapted to align a wafer with a target is shown, in accordance with one embodiment of the present invention. Stepper 202 includes a stage 208 coupled to a stage movement device 210, a processor 212, a signal transceiver 204, and a

15   memory 214. Wafer 206 is placed on stage 208 for processing in stepper 202. Memory 214 contains program instructions that, when implemented through processor 212, allow stepper 202 to implement the steps used in the present invention to determine the centroid of a target on a wafer. Flowchart 4000, presented hereinafter, provides one embodiment of these steps.

20

Memory 214 for the present embodiment can either be permanent, such as read only memory (ROM), or temporary memory such as random access memory (RAM). Memory 214 can also be any other type of memory storage, capable of containing program instructions, such as a hard drive, a

25   CD ROM, or flash memory. Furthermore, processor 212 can either be an existing system processor or microprocessor, a dedicated digital signal processing (DSP) processor unit, or a dedicated controller or

microcontroller. Alternatively, the instructions may be implemented using an implementation of a state machine.

Signal transceiver 204 is coupled to processor 212. Signal
5 transceiver 204 is a source of an electromagnetic signal, such as a laser. Additionally, signal transceiver 204 is a receiver for an electromagnetic signal, such as the return signal that is reflected from a wafer. In this manner, the signal transceiver 204 can be utilized, as described in flowchart 4000 as one embodiment, to satisfy the steps of the present invention.
10 Signal transceiver 204 can be any one of many well-known transceiver configurations.

Referring now to Figure 3A, a portion of a wafer 300 with an alignment target formed therein is shown, in accordance with one embodiment of the
15 present invention. Figure 3A shows a top view of wafer 300 located in an X-Y plane. Wafer 300 has four alignment targets 304a, 304b, 304c, and 304d, in the present embodiment. Alignment targets 304a-304d can be grouped into two sets to form larger virtual targets, in one embodiment. For example, targets 304a + 304b can be grouped together to create a virtual target 313a.
20 Similarly, targets 304c + 304d can be grouped together to create a virtual target 313b. Virtual target 313a uses the conventional smaller targets 304a and 304b to define the sides of the larger virtual rectangle. Thus, while the larger virtual rectangle, e.g. 313a, does not really exist, because it does not have a top and bottom as shown in dashed lines, it does have side walls that
25 can be evaluated by the stepper. Virtual targets 313a and 313b are separated by land of material 315. Beneficially, this method can use either conventional or modified targets with which to create the larger virtual targets.

Targets, or target shapes, 304a-304d are rectangular in shape, having a height 307a of approximately 30 microns (μ), a width 307c of approximately 4μ, and a pitch 307b of approximately 20μ. Targets 304a-304d are separated by pitch distance 307b of material referred to as a "land" of material. One such land 305 shown between targets 304c and 304d. The present invention arranges targets sequentially in the X-direction, to determine a centroid in the X-direction. A direction of CMP operation is indicated by arrow 311.

The present invention is well-suited to alternatives from the embodiment shown in Figure 3A. For example, while the present embodiment utilizes a specific shape of targets, quantity of targets, and grouping of targets to create a specific quantity of larger virtual targets, the present invention is well suited to many alternatives. Also, the present invention can have targets with many different sizes, configurations and orientations. Furthermore, the present invention is well-suited to arranging targets in alternative directions to determine a centroid in the alternative directions, e.g. the Y-direction. Additionally, the present invention is suitable to using any quantity of sets of targets with any quantity of target shapes within the target set. In one embodiment, additional sets of targets are used to provide multiple data points that can be averaged to determine the final centroid. The averaging is utilized to remove noise arising from the target formation and the centroid determining process.

The present invention is well-suited to placing targets 304a-304d in silicon substrate, an oxide layer, or some other layer of material on the wafer.

Target shapes 304a-304d can be either separate entities, or they can be joined together, e.g. at one or both ends, so long as a land of material different from the target material, exists between the targets. The land of material between targets, e.g. 304a-304d, can be any material that will

5   provide a return signal that can be distinguished form the return signal from the target surface.

Referring now to Figure 3B, a different view of wafer 300 with the alignment target of Figure 3A is shown, in accordance with one embodiment

10   of the present invention. Specifically, Figure 3B shows a cross-sectional view taken along line A-A of Figure 3A. Centroid 309c represents the centroid of targets 304a-304d. Targets 304a-304d have a depth 307d in layer 303, made of silicon dioxide in one embodiment. However, the present invention is well-suited to targets having any depth in a layer of any type

15   material. Layer 308 of metal material, existing above targets 304a-304d, conforms to the surface of targets 304a-304d and layer 303. Thus, flat portions of layer 308 exist above flat portions of layer 303, such as the flat land area 305 above a flat portion of layer 303. Similarly, a concave surface of layer 308 exists above the concave surface of targets, such as the

20   concave surface 306 located proximately above target 304b. A layer of photoresist material 316, which does not conform to surface irregularities, is deposited above layer 308. Two instances of a light source used to evaluate the surface of layer 316 is shown as light source 301a and 301b. The reflection from light source 301a and 301b off of layer 316 of wafer 300

25   is detected by detector 302.

Referring now to Figure 3C, a graph 300c showing a signal with an extrema used to determine a centroid of a target, or a target set, is shown in

accordance with one embodiment of the present invention. Graph 300c of

Figure 3C has an ordinate axis of intensity 320 and an abscissa axis of

location on a wafer 322. Return signal 324, shown in Figure 3C, represents

the portion of return signal reflected from a flat portion of material separating

5 concave portions of layer over targets. Signals reflected from concave

portions of layer over targets is shown by cross-hatched areas 334a-334d in

Figure 3C, which correspond to targets 304a-304d of Figure 3A. This

material area is shown in Figure 3B as portions of material layer 308 in wafer

300 separating targets 304a-304d, e.g. land 305. The material 308 can be a

10 variety of materials or layers as described in Figure 3B. In the present

embodiment, the extrema is a maxima. That is, maxima 1 321, maxima 2

322, and maxima 3 323 represent a maximum intensity of return signal 324.

As an example, maxima 3 323 signal represents the reflected signal 301b

from top surface 305 of layer 308 that corresponds to the land of material

15 separating targets 304c and 304d in a submerged layer.

Still referring to Figure 3C, a maxima is defined as a point where a

slope of zero exists, where slope polarity changes sign, e.g. between a

positive slope and a negative slope, and where a positive slope exists on the

20 left side of the maxima. As an example, slope 1 328 and slope 2 329 are

opposite polarity slopes on either side of maxima 3 323. The same slope

scenario exists for maxima 1 321 and maxima 2 322. A centroid is a center

of mass, or a geometric center, of 1 or more targets. For example, centroid A

309a represents maxima 1 321 as the centroid of virtual rectangle target

25 313a. Similarly, centroid B 309b represents maxima 3 323 as the centroid of

virtual rectangle target 313b. Centroid 309c represents a median centroid

for all targets, e.g. the centroid between virtual targets 313a and 313b.

The present invention avoids the problems associated with the conventional method using return signals from target surface, represented by cross-hatch areas 334a-334d in Figure 3C and represented by areas 134 and 135 in prior art Figure 1B. The present invention accomplishes its more

5   accurate centroid calculation by using return signal from material areas, with better flatness and symmetry properties, that separate the targets. An example of the material areas responsible for max 3 323 is the flat land 305 area shown in Figure 3B, where light signal 301b is reflected with nearly a zero angle of reflection, and thus provides a high intensity reading from

10   detector 302.

The embodiment of the present invention shown in Figure 3C is suitable to several alternatives. For example, the slopes and shape of return signal 324 are exemplary, and can have alternative features in another

15   embodiment. Furthermore, the spacing of maxima is dependent upon the location of targets, and thus, will be different for alternative target shapes, sizes, and locations.

Referring now to Figure 4, a flowchart 4000 of the steps performed to

20   determine a centroid of a target set in a wafer is shown, in accordance with one embodiment of the present invention. By using the embodiment of flowchart 4000, the present invention provides a method that more accurately determines the centroid of the targets having adverse flatness and symmetry conditions. While the present invention utilizes flowchart

25   4000 for determining the centroid of targets on a wafer in a stepper, the present invention is well-suited to finding centers, averages, or centroids of targets or of some product patterns, on a wafer, a layer of a wafer, or another article as held by a stepper, a calibration machine, or some other device.

Flowchart 4000 begins with step 4002. In step 4002 of the present embodiment, a wafer is received. In one embodiment, the wafer already has a plurality of target shapes formed therein. Step 4002 is implemented, in

5   one embodiment, with wafer 300 of Figure 3A and 3B, that has targets 304a-304d formed therein. Step 4002 is also shown in Figure 2 where wafer 206 is received in stepper 202.

Step 4002 is well-suited to alternative embodiments. For example,

10   the present invention is well-suited to having any number of targets of any size, shape, or configuration that are oriented in any direction. In another embodiment, the number of target shapes must be at least two so as to provide at least one "land" of material between the two targets. In an alternative embodiment, only one target can be used, so long as some other

15   feature nearby the target provides a "land" of material that can have an extrema, e.g. a maxima point. In one embodiment, the land of material can be any material so long as it provides a return signal that can be distinguished from a return signal from the target. As shown in Figure 3B, other layers of material usually cover the target. For example, layer 308 of

20   metal covers targets 304a-304d. Above layer 308 is layer 316 of photoresist material. The combination of photoresist material 316 and metal layer 308 of the present embodiment allow the creation of metal patterns in layer 308. That is, a pattern for IC lines can be formed on photoresist layer 316, from a pattern on a mask, and subsequently etched in metal layer 308. Accurate

25   identification of the location of targets, e.g. targets 304a-304d, afforded by the present invention allows accurate formation of patterns in subsequent layers. Following step 4002, flowchart 4000 proceeds to step 4004.

In step 4004 of the present embodiment, a signal is passed over the target set and over the material separating the plurality of target shapes. Figure 2 shows one embodiment of the present step 4004. In Figure 2, signal transceiver 204 is adapted to provide a signal passed across wafer

5   206. Well-known methods and apparatus can provide a wide range of signal properties, e.g. signal direction, intensity, and control, for step 4004. In one embodiment, the signal is passed over a target set and material land between target shapes in a single pass. Step 4004 can be implemented, in one embodiment, on wafer 300. In this embodiment, a signal is passed over

10   targets 304a-304d and the lands of material separating each target shape. The signal is an electromagnetic signal in one embodiment. More specifically, the signal is a laser signal generated from any one of many well-known lasers utilized for target acquisition. Figure 3B shows one embodiment implementing step 4004. In Figure 3B, signal 301a is

15   transmitted onto concave surface, of layer 308, formed in response to concave surface of target 304a.

Step 4004 is well-suited to alternative embodiments. For example, signal transceiver 204 includes the alternative configurations provided for

20   Figure 2. Furthermore, the signal can be passed over a single target set, shown in Figure 3A and 3B. Besides using a laser signal, the present invention is well-suited to alternative signal types, such as an electron beam signal. Following step 4004, flowchart 4000 proceeds to step 4006.

25   In step 4006 of the present embodiment, a return signal is received. Figure 2 shows one embodiment of the present step 4006. In Figure 2, a return signal is received by signal transceiver 204 from wafer 206. Step 4006 is also implemented by the embodiment as shown in Figure 3A and

3B. In Figure 3B, signal 301a is not received by detector 302 because the surface of layer 308 causes signal 301a to reflect at an angle, thus missing the detector 302. This low amplitude return signal is shown by a low intensity value 325 on the left wide of max 1 321 of Figure 3C. In contrast,

5   signal 301b is reflected with nearly zero angle of reflection from surface 305, because it is flat, and thus detector 302 receives a strong return signal. This high amplitude return signal is shown by a high intensity, e.g. max 3 323, in Figure 3C. This step uses well-known methods and apparatus to receive the return signal.

10

The present invention is well-suited to alternatives from the embodiments described for step 4006. For example, the return signal can be received by a receiver device that is separate from the signal transmitter device. Additionally, while the present embodiment, shown in Figure 2, has

15   no magnification or interim modification of signal between signal transceiver 204 and wafer 206, the present invention is well-suited to some interim modification of signal. Furthermore, the present invention is well-suited to detecting target location under a layer of material other than the reflective metal layer 308 used in the present embodiment. In this alternative

20   embodiment, the return signal 324 of Figure 3A may have different minima or maxima responses due to the different reflective properties of the alternative material layer. Following step 4006, flowchart 4000 proceeds to step 4008.

In step 4008 of the present embodiment, an extrema of the return

25   signal is identified. In the present embodiment, only the return signal generated from the land of material separating target shapes, as noted in step 4006, is analyzed for the extrema location. Figure 3C shows one embodiment of the present step 4008 where maxima 1 321 and maxima 3

323 are maximum intensities for a return signal generated from lands of material between targets. Maxima 1 321 of Figure 3C represents the maxima for virtual rectangle target 313a. Similarly, maxima 2 322 of Figure 3C represents the maxima for virtual rectangle target 313b. The maximum

5   intensity can be determined for a return signal from all lands that provide a return signal. The present embodiment utilizes a maxima point of a return signal for identifying the maximum intensity of return signal, as discussed in Figure 3C.

10   Step 4008 can be implemented by programming a stepper, in one embodiment, the present embodiment would program the stepper to recognize the two virtual rectangles. Thus, the present embodiment would program the stepper to recognize only 2 rectangles, e.g. virtual rectangles 313a and 313b of Figure 3A, having a width of approximately 28 μ each, e.g.

15   width 305 of Figure 3A, and spaced apart by approximately 20 μ, e.g. land 315. In contrast, the conventional method would program the stepper to recognize 4 rectangles having a width of approximately 2-4 μ each, and a spacing of approximately 20 μ. However, given the noisy signal arising from contamination in the layers formed over each individual target, the accuracy

20   of the location of the target, which may not even be acquirable, would be very poor. Consequently, the present invention, by using virtual targets formed from individual targets, greatly increases target acquisition rate and centroid accuracy.

25   Step 4008 is well-suited to alternative embodiments. For example, while two maxima are used in step 4008, resulting from lands between four targets, the present invention is well-suited to having only two targets that create only one maxima point from the material in between. This

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embodiment can be implemented in Figure 3A by having only targets 304a and 304b provide a maxima 1 321 of Figure 3C. Furthermore, the maximum intensity of a return signal can be determined by sampling and comparison of maximum discrete values, in lieu of a maxima determined by slope. While the present invention utilizes a maximum intensity of a return signal for determining a centroid between targets, the present invention is well-suited to using an alternative extrema. For example, if the land of material separating targets is more signal-absorbing, rather than more signal-reflective, than the targets, then the present invention could utilize a minimum intensity point as the centroid of the land, or as the centroid of the target set. Following step 4008, flowchart 4000 proceeds to step 4010.

In step 4010 of the present embodiment, a centroid for target sets is determined from the extrema of the return signal. In the present embodiment, three target sets are used on a wafer. Thus, the centroid is determined from the average value of the two extrema, e.g. maximum intensity points, of the return signal from the two outer material lands separating the target shapes in each target set. Figure 3C shows one embodiment of the present step 4010. In Figure 3C, centroid 309c of the target set is determined by the average of locations of maxima 1 321, shown as centroid A 309a, and of maxima 3 323, shown as centroid B 309b. The centroid calculation can be appropriately offset from a standard measuring reference, or from each other. Centroid 309c is provided in the X-direction only for the present embodiment. Location of centroid 309c can be calculated using a centroid calculation, e.g. equation 1.1, or using an averaging equation, e.g. equation 1.2.

(Eq. 1.1)   Centroid = $[\Sigma \text{ (location Maxima n)}] / m$

where: n = 1, m;   m = quantity of extrema

(Eq. 1.2)   Centroid = [(Maxima 1 + Maxima 3)] / 2

Step 4010 is well-suited to alternative embodiments. For example, in lieu of simple averaging, the present invention is well-suited to weighting the locations of different extrema intensity points, depending upon their location, accuracy, or signal response characteristics. Additionally, the present invention can utilize interim centroids in lieu of maximum intensity points for determining centroid of multiple target steps. However, this alternative embodiment provides a different method, with associated benefits of alternative weighting techniques to determine the ultimate composite centroid. Additionally, targets can be oriented in an alternative direction to provide a centroid in the alternative direction.

As an alternative embodiment to step 4010 maxima 3, not used for determining overall centroid 309c in the present embodiment, can be utilized. Similarly, the maxima and centroids may be programmed differently. For example, even though all maxima shown in Figure 3C may be detected by detector 302 of Figure 3B, one embodiment of the present invention may be tailored to only detect one of them. For example, the stepper can be programmed to see signal 334a of Figure 3C arising from target 304a of Figure 3B as one side of an even larger virtual rectangle, not shown. Similarly, the stepper can be programmed to see signal 334d of Figure 3C arising from target 304d of Figure 3B as the other side of the even larger virtual rectangle. Consequently, it would identify maxima 2 322 of Figure 3C as the centroid of the even larger virtual rectangle. The stepper could be programmed to regard maxima 1 321 and maxima 3 323 as noise, and thus ignored.

Many of the instructions for the steps, and the data input and output from the steps, of flowcharts 4000 utilize memory and utilize controller hardware shown in Figure 2. For example, wafer 206, stage 208, and signal

5   transceiver 204, can be controlled by memory 214 and processor 212 to accomplish the requirements steps in flowchart 4000. The alternative embodiments of Figure 2 are equally applicable to implementing the steps of flowchart 4000. In one embodiment, software in memory 214 does not need to be modified for the new process. Instead, the software can be fooled into

10   measuring the desired maxima points by having a user input a number of targets that misrepresents the actual number of targets, but beneficially produces the desired results of flowchart 4000.

While flowchart 4000 of the present embodiment shows a specific

15   sequence and quantity of steps, the present invention is suitable to alternative embodiments. For example, not all the steps provided for flowchart 4000 are required for the present invention. Furthermore, the present invention is well-suited to an embodiment which includes additional steps to flowchart 4000. Likewise, the sequence of the steps can be

20   modified depending upon the application. Furthermore, while flowchart 400 is shown as a single serial process, it can also be implemented as a continuous or parallel process. Many of the instructions for the steps, and the data input and output from the steps, of flowchart 4000 utilize memory and controller hardware shown in Figure 2.

25

Referring now to Figure 5A, a first configuration of a target pattern 507 of mask 500a that is highly tolerant to asymmetry and non-flatness is shown, in accordance with one embodiment of the present invention. Figure 5A

shows a sawtooth target pattern, symmetric about an axis in the Y-direction. Target pattern 507 is shown as a target pattern on a mask, or reticle. However, the reticle 500a can be used to form this same pattern, or its negative, on a wafer. Sawtooth pattern 500a has multiple fingers, e.g. such

5   as exemplary fingers 502, coupled to a spine 504. Spine 504 extends lengthwise in the Y-direction, while fingers, such as fingers 502 on both sides of spine 504 extend lengthwise in a perpendicular direction to spine 504, e.g. extend in the X-direction. By having a sawtooth edge, e.g. 502, on either side of spine 504, the present invention provides a target shape that

10   is not sensitive to the edge conditions of the target. Background 509 of mask 500a surrounds target pattern 500a. That is, only the small area of tip, e.g. 503, of target shape 507 will be subject to the edge irregularities of asymmetry and non-flatness arising with conventional CMP methods and apparatus.

15

Alignment target 500a of Figure 5A has a width 508 of 20µ and a height 506 of 30µ in one embodiment. However, the present invention is well-suited to a wide range of heights and widths of alignment target. In one embodiment, the dark pattern of target 507 is a chrome material on a mask,

20   or a reticle. In the present embodiment, background 505 is transparent. In this configuration, light shines through background 505 to create a pattern that will subsequently form a trench in a layer of material on a wafer. However, the present invention is well-suited to alternative materials, use of gray scale shades for target and background, and to using a negative of the

25   pattern. In another embodiment, pattern 500c is a target pattern existing in a layer of material in a wafer.

By using the present invention, such as the embodiment of Figure 5A, a more accurate target location can be obtained using the spine and finger configuration target shape in lieu of a conventional rectangular target shape. While the sawtooth fingers 502 of the present embodiment may increase

5 noise in the return signal, the return signal from spine 504 of target pattern 500a should rise above the noise to provide a sharp distinctive extrema for the intensity return signal as shown in Figure 5C. Additionally, while the spine and fingers of Figure 5A are shown with a particular shape, quantity, configuration, and orientation, the present invention is well-suited to many

10 different configurations, orientations, shapes, and quantities of target pattern that are highly tolerant to, or immune from, asymmetry and non-flatness of surface arising from conventional CMP process and materials.

Referring now to Figure 5B, a second configuration of a target pattern

15 507 on mask 500b that is highly tolerant to asymmetry and non-flatness is shown, in accordance with one embodiment of the present invention. Figure 5B shows a rectangular-tooth pattern, symmetric about an axis in the Y-direction. Target pattern 500b can exist as a pattern on a mask, or reticle, or as a pattern formed on a silicon wafer from the mask. Figure 5B includes a

20 rectangular spine 504 extending in the Y-direction. Fingers 502 extend perpendicular from spine 504, e.g. extend in the X-direction. Instead of the sawtooth shape shown in Figure 5A embodiment, the Figure 5B embodiment has fingers with a rectangular shape. Background 509 of mask 500b surrounds target pattern 507. The same benefits and alternative available to

25 the embodiment of Figure 5A apply to Figure 5B.

Referring now to Figure 5C, a wafer 500c with a target having asymmetry and flatness immunity is shown, in accordance with one

embodiment of the present invention. Wafer 500c has a first target shape

546 and a second target shape 548. First target shape 546 is spaced a

distance 538a away from second target shape 548. The target shapes

provide a centroid in the X-direction. In one embodiment, first and second

5   target shapes 546 and 548 are essentially a negative image of a target

pattern similar to the target pattern 507 shown in Figure 5A. In one

embodiment, height 538b of target is 40 microns (μ), width 538c of target

pattern is 24 μ, and distance 538a between multiple targets is 16 μ.

However, the present invention is well-suited to a wide range of dimensions

10   for a target, and a wide range of distances separating multiple targets. While

the present embodiment shows target shapes having a specific geometry,

orientation, and quantity, the present invention is well-suited to many

alternative geometries, orientations, and quantities of target shapes

15   Referring now to Figure 5D, the wafer 500c of Figure 5C is shown, in

accordance with one embodiment of the present invention. Specifically,

Figure 5D shows wafer 500c in a cross-sectional view, e.g. View B-B.

Similar to Figure 3B, Figure 5D includes a first layer 566 located above a

substrate 564 of wafer 500c. In layer 566, a pattern similar to patter 500a of

20   Figure 5A is etched to provide trenches that are filled with metal, e.g. metal

560 in trench. Lands of the original layer of material 566 exist between filled

trenches 560. These lands are shown as items 561, 562, and 563. Above

the lands exists a layer of material 567, such as metal, that somewhat

conforms to the surface of trenches 560 and of layer 566. On top of layer

25   567 is a layer of photoresist 568, upon which an image will be patterned.

Dashed lines 569 above trenches 560 represents how sawtooth pattern 542

shown in Figure 5C provides a varying trench depending whether View B-B

is taken at the peak-to-peak portion of the sawtooth pattern 540 or from the

root-to-root portion of the sawtooth 540. The effect from the sawtooth pattern is repeated in subsequent layer 567 where dashed lines 572 represent how layer 567 fills in the sawtooth pattern existing in trenches 560 of the underlying layer. Similarly, land 571 in layer 567 is proximately adjacent

5   and conformal to top surface of land, e.g. top surface 561 of land 566, in the underlying layer.

Referring now to Figure 5E, a graph 500e of a return signal from a wafer target that is highly tolerant to asymmetry and non-flatness is shown, in

10   accordance with one embodiment of the present invention. Graph 500e of Figure 5E has an ordinate axis of intensity 520 and an abscissa axis of location 522. Return signal 521 shown is Figure 5E represent the portion of return signal 524, shown in Figure 5D, that is reflected from a material area of wafer separating targets, e.g. lands 566. Thus, maxima 1 521 in Figure 5E

15   is signal 521 in Figure 5D reflected from flat land 571 of layer 568 that effectively indicates the land of material separating targets in the underlying layer. In contrast, return signal 530 of Figure 5D does not show as return signal 524 of Figure 5E because the angle of reflection significantly reduces the intensity of the return signal to detector 302a.

20

In one embodiment, improved target pattern 507 of Figure 5A can be substituted for target 304a-304d of Figure 3A. Return signal 524 of Figure 5E has an impulse-like response corresponding to the spine, e.g. spine 504 of Figure 5A or spine 542 of Figure 5C. That is, the extrema, e.g. maximum 1

25   521 and maximum 2 522, of graph 500e of Figure 5E are much more pronounced than the extrema, e.g. maximum 1 321, maximum 2 322, and maximum 3 323, of a return signal, e.g. 324, from a target without the improved edge configuration as shown in Figure 3A-3C. Thus, the change

in slope from a negative slope 526a to a positive slope 526b for return signal 524 from the improved target configuration occurs over a smaller distance, e.g. over a very small span, e.g. span 531, to obtain the extrema, in one embodiment of the present invention. Hence, the present invention

5   significantly narrows the range of error in comparison to conventional methods and apparatus. Additionally, the ratio of maximum signal to a minimum signal is much higher for the present invention than for the prior art. Figure 5E shows one embodiment of this higher maximum to minimum signal ratio as the maximum MAX 1 521 divided by MIN 1 530, and as shown

10   by span 531 between maximum 1 521 and minimum 530. This higher ratio translates into an improved target from which a more accurate target centroid can be determined.

        The application of graph 500e, and the alternatives available for the

15   data of graph 500e are similar to those presented for graph 300c of Figure 3C. Similarly, Flowchart 4000 is also applicable to the target designs of Figure 5A and 5B.

        In summary, the present invention provides an apparatus and a

20   method that ensures accurate formation of patterns on adjacent layers of the wafer by providing accurate target location. Additionally, the present invention provides an apparatus and a method that will accurately locate a target on a wafer regardless of the flatness of the target surface. Furthermore, the present invention provides an apparatus and a method that

25   will accurately locate the target on a wafer regardless of the asymmetry of the target surface. The proposed apparatus and method has an increased target acquisition rate, using either a conventional or a modified target. Finally, the present invention provides a target design is immune from the

asymmetry and non-flat surfaces likely to arise in conventional CMP processes.

The foregoing descriptions of specific embodiments of the present invention have been presented for purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed, and obviously many modifications and variations are possible in light of the above teaching. The embodiments were chosen and described in order best to explain the principles of the invention and its practical application, to thereby enable others skilled in the art best to utilize the invention and various embodiments with various modifications as are suited to the particular use contemplated. It is intended that the scope of the invention be defined by the Claims appended hereto and their equivalents.

I Claim:

1. A method of determining a centroid of a target set in a wafer, said method comprising the steps of:

5   a) receiving said wafer, said wafer having said target set formed therein, said target set including a plurality of target shapes separated by a material;

      b) passing a signal over said plurality of target shapes and over said material of said target set;

10   c) receiving a return signal that is reflected from said plurality of target shapes and from said material separating said plurality of target shapes within said target set;

      d) identifying a location of each of at least one extrema of said return signal reflected from said material separating said plurality of target shapes

15 within said target set; and

      e) determining said centroid of said target set from said at least one extrema of said return signal.

2. The method recited in Claim 1 wherein said extrema is a maxima

20 point.

3. The method recited in Claim 1 wherein said signal is a laser signal.

4. The method recited in Claim 2 wherein said maxima point is

25 determined from a slope of an intensity of said return signal, said slope existing on either side of said maxima point.

5. The method recited in Claim 1 wherein said plurality of target shapes includes two rectangular target shapes.

6. The method recited in Claim 5 wherein only one maxima point is
5 generated.

7. The method recited in Claim 6 wherein said centroid is located at said one maxima point.

10   8. The method recited in Claim 1 wherein said plurality of target shapes includes four rectangular target shapes.

9. The method recited in Claim 8 wherein said extrema of said step d) are comprised of three maxima points, said three maxima points including
15 two outer maxima points and a center maxima point.

10. The method recited in Claim 9 wherein a location of said centroid is based on a median location between said two outer maxima points, averaged with a location of said center maxima point.
20

11. The method recited in Claim 9 wherein a location of said centroid is based on a centroid calculation using a location of all three maxima points.

25   12. A stepper for aligning a wafer, said stepper comprising:
     a processor; and
     a computer readable memory, said computer readable memory
coupled to said processor, said computer readable memory containing

program instructions stored therein that when executed over said processor implement a method for determining a centroid of a target set in said wafer, said method comprising the steps of:

a) receiving said wafer, said wafer having said target set formed therein, said target set including a plurality of target shapes separated by a material;

b) passing a signal over said plurality of target shapes and over said material of said target set;

c) receiving a return signal that is reflected from said plurality of target shapes and from said material separating said plurality of target shapes within said target set;

d) identifying a location of each of at least one extrema of said return signal from said material separating said plurality of target shapes within said target set; and

e) determining said centroid of said target set from said at least one extrema of said return signal.

13. The method recited in Claim 12 wherein said signal is a laser light signal.

14. The method recited in Claim 12 wherein said extrema is a maxima point determined from a slope of said intensity of said return signal, said slope existing on either side of said maxima point.

15. A reticle for creating an alignment image on a wafer, said reticle comprising:

a target pattern having a spine extending in one direction and having a plurality of fingers coupled to, and extending perpendicular to said

direction of, said spine, said plurality of fingers having a gap between each other; and

a background located outside of said pattern.

5   16. The reticle recited in Claim 15 wherein said target pattern is opaque.

17. The reticle recited in Claim 15 wherein said background is transparent.

10

18. The reticle recited in Claim 15 wherein said target pattern is a sawtooth pattern that is symmetrical about an axis of said solid spine.

19. The reticle recited in Claim 15 wherein said target pattern is a set

15   of rectangles that is symmetrical about an axis of said solid spine.

20. A wafer capable of being used for alignment in a stepper, said wafer comprising:

a substrate;

20   a target, said target having a solid spine in one direction and having a plurality of fingers coupled to, and extending perpendicular from, an axis of said spine, said plurality of fingers having a gap between each other.

21. The wafer recited in Claim 20 wherein said pattern is a sawtooth

25   pattern that is symmetrical about said solid spine.

22. The wafer recited in Claim 20 wherein said pattern is a set of rectangles that is symmetrical about said solid spine.
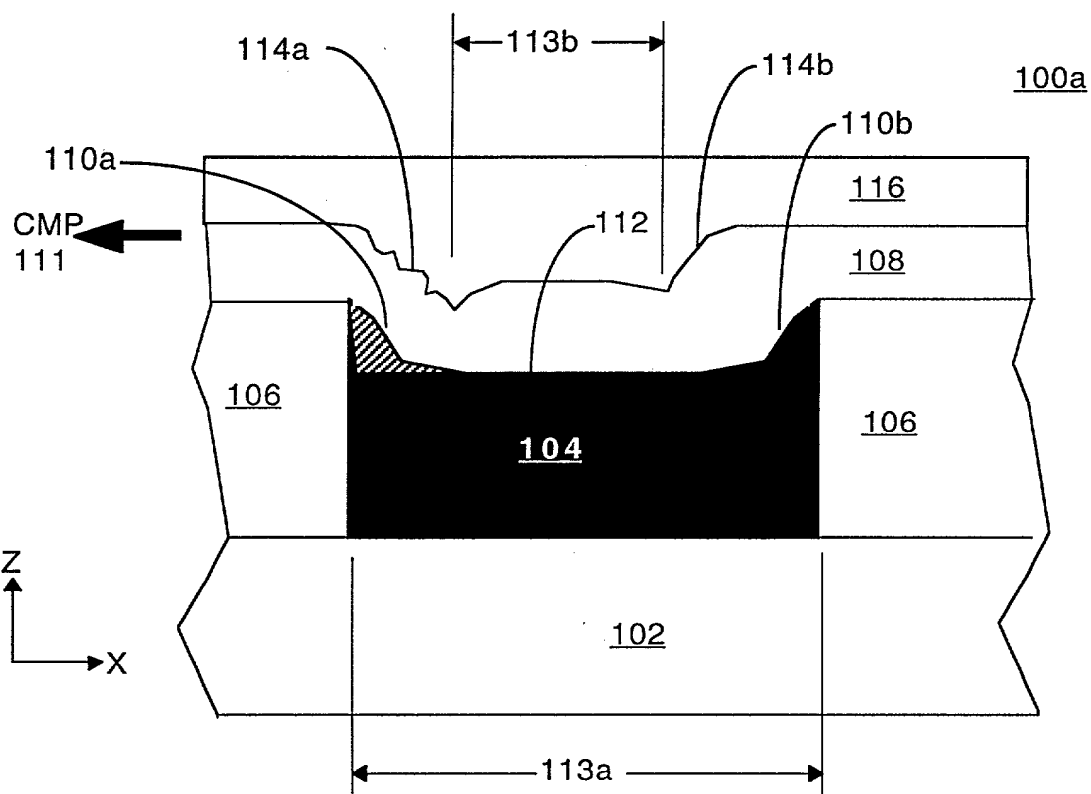
WAFER TARGET DESIGN AND METHOD FOR DETERMINING CENTROID
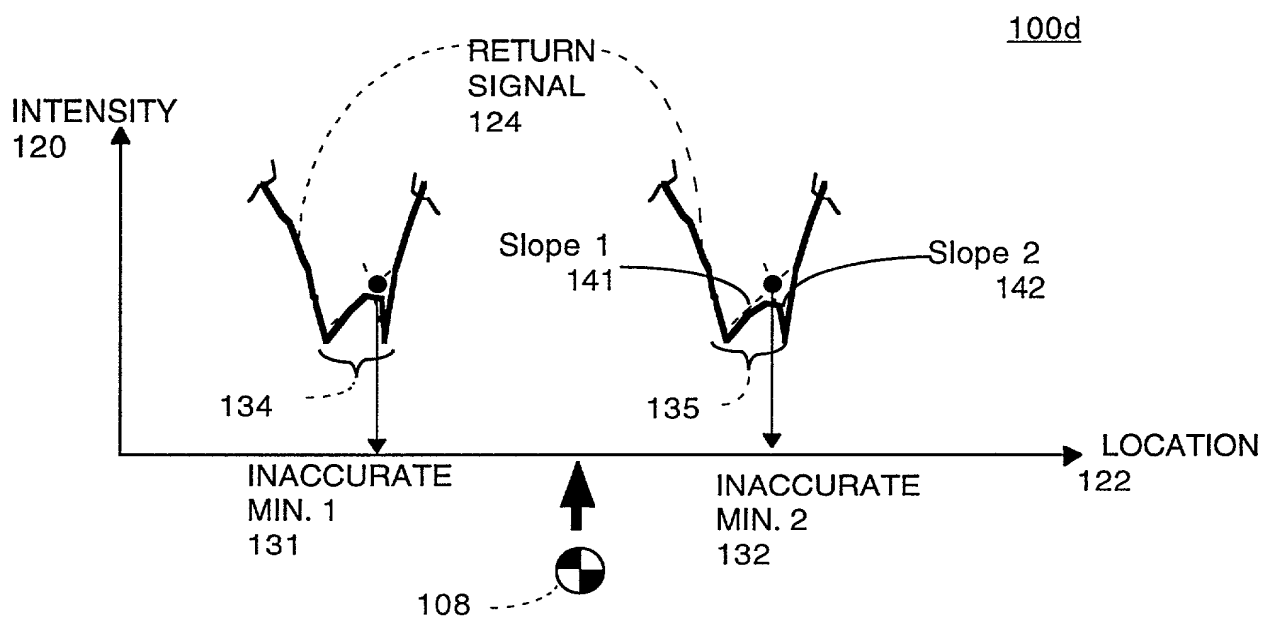# OF WAFER TARGET

ABSTRACT OF THE DISCLOSURE

5

A method for determining the centroid of a wafer target. In one embodiment, the method comprises a series of steps in a stepper, starting with the step of receiving a wafer, having a target set formed therein. Next, a signal is passed over the target set and over a material separating target

10   shapes in the target set. Then a return signal is reflected, and received, from the surface of the target shapes and the material separating them. A location of at least one maxima point of the return signal is identified. Finally, a centroid is determined as the median of the locations of at least one maxima point.

Prior Art Fig. 1A
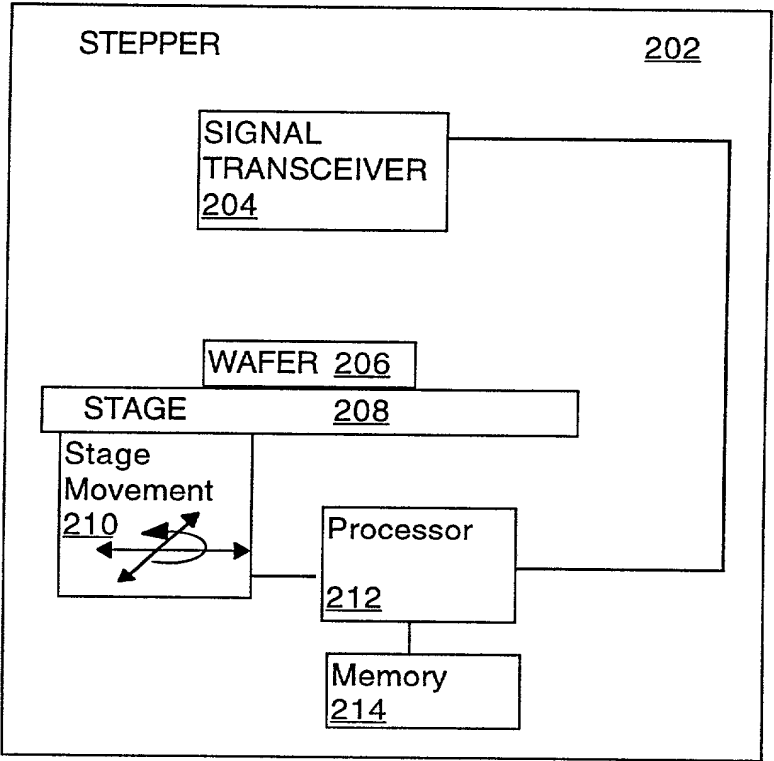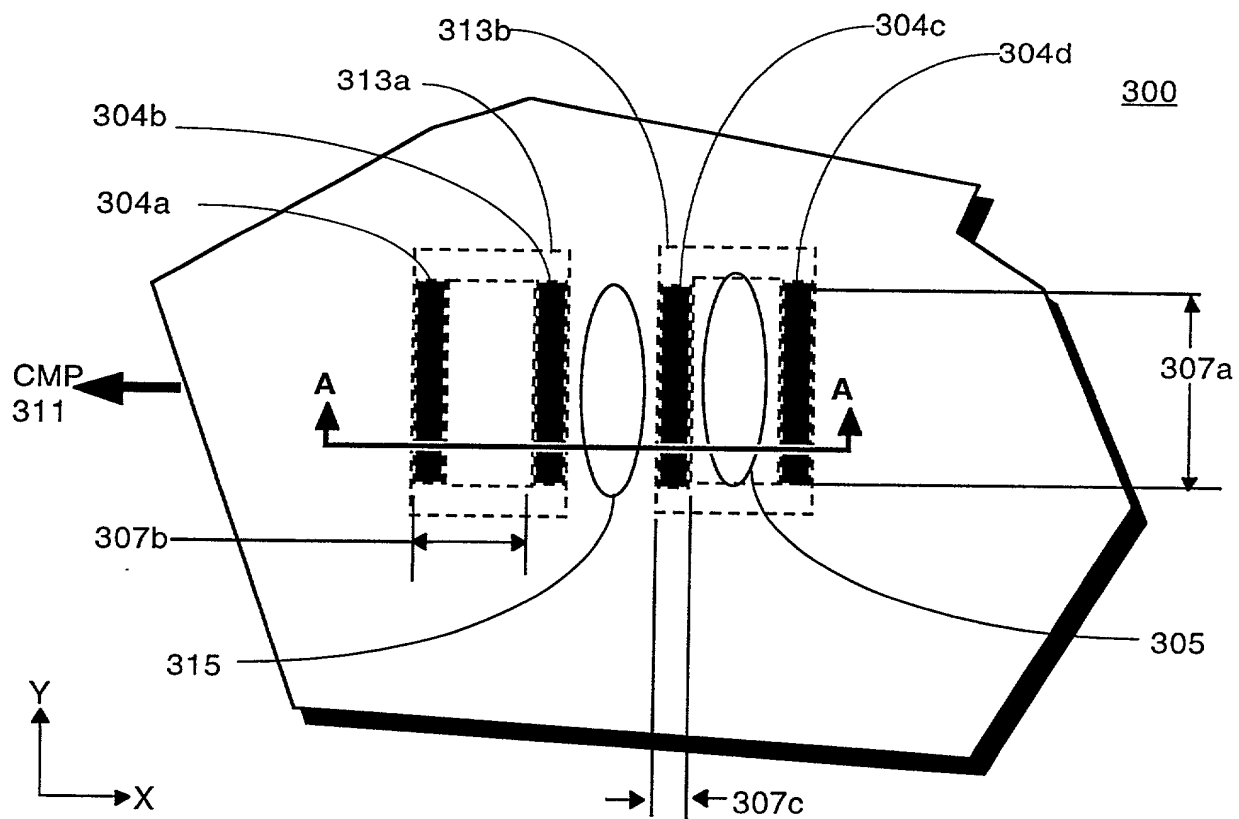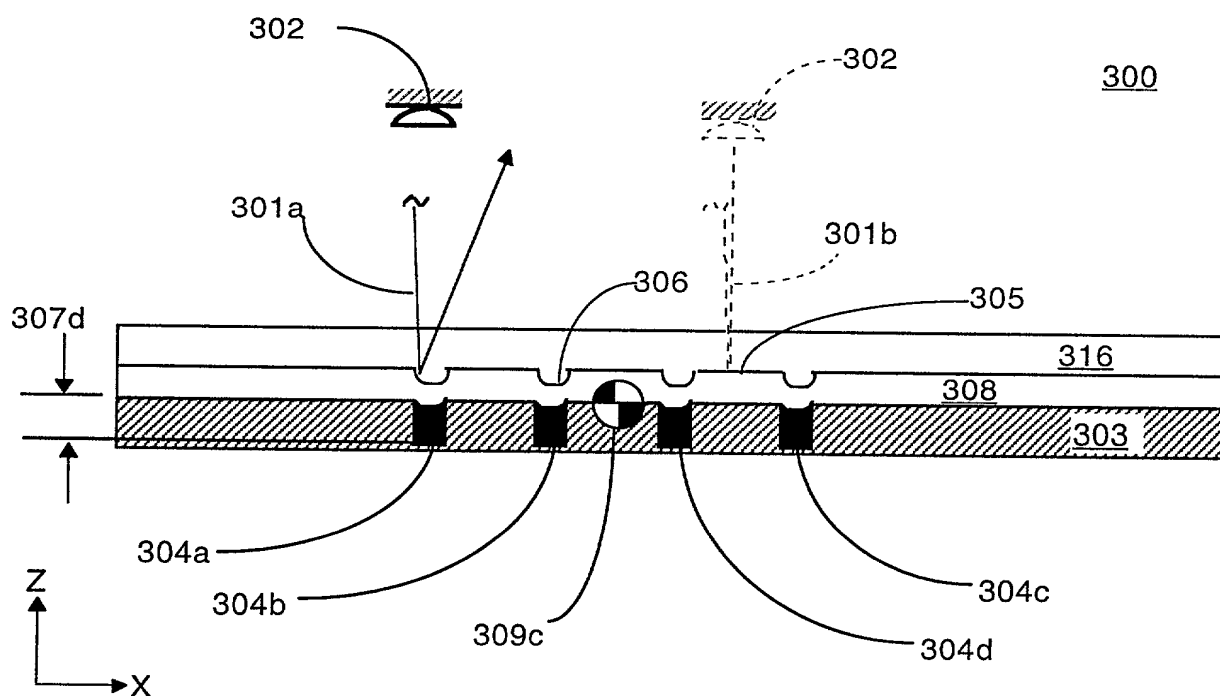

Prior Art Fig. 1B

STEPPER   202

SIGNAL TRANSCEIVER 204

WAFER 206

STAGE   208

Stage Movement 210

Processor 212

Memory 214

Fig. 2

Fig. 3A

VIEW A-A

Fig. 3B

INTENSITY
320

MAX 1
321

MAX 2
322

Slope 1
328

MAX 3
323

ACCURATE
SIGNAL 324

Slope 2
329

LOW
INTENSITY
325

334a
334b

334d
334c

LOCATION
322

CENTROID A
309a

CENTROID B
309b

OVERALL
CENTROID
309c

Fig. 3C

START

Receive wafer having target set including a plurality of target shapes   4002

Pass signal over target set and over material separating plurality of target shapes   4004

Receive return signal reflected from target set and material   4006

Identify a location of intensity extrema of return signal   4008
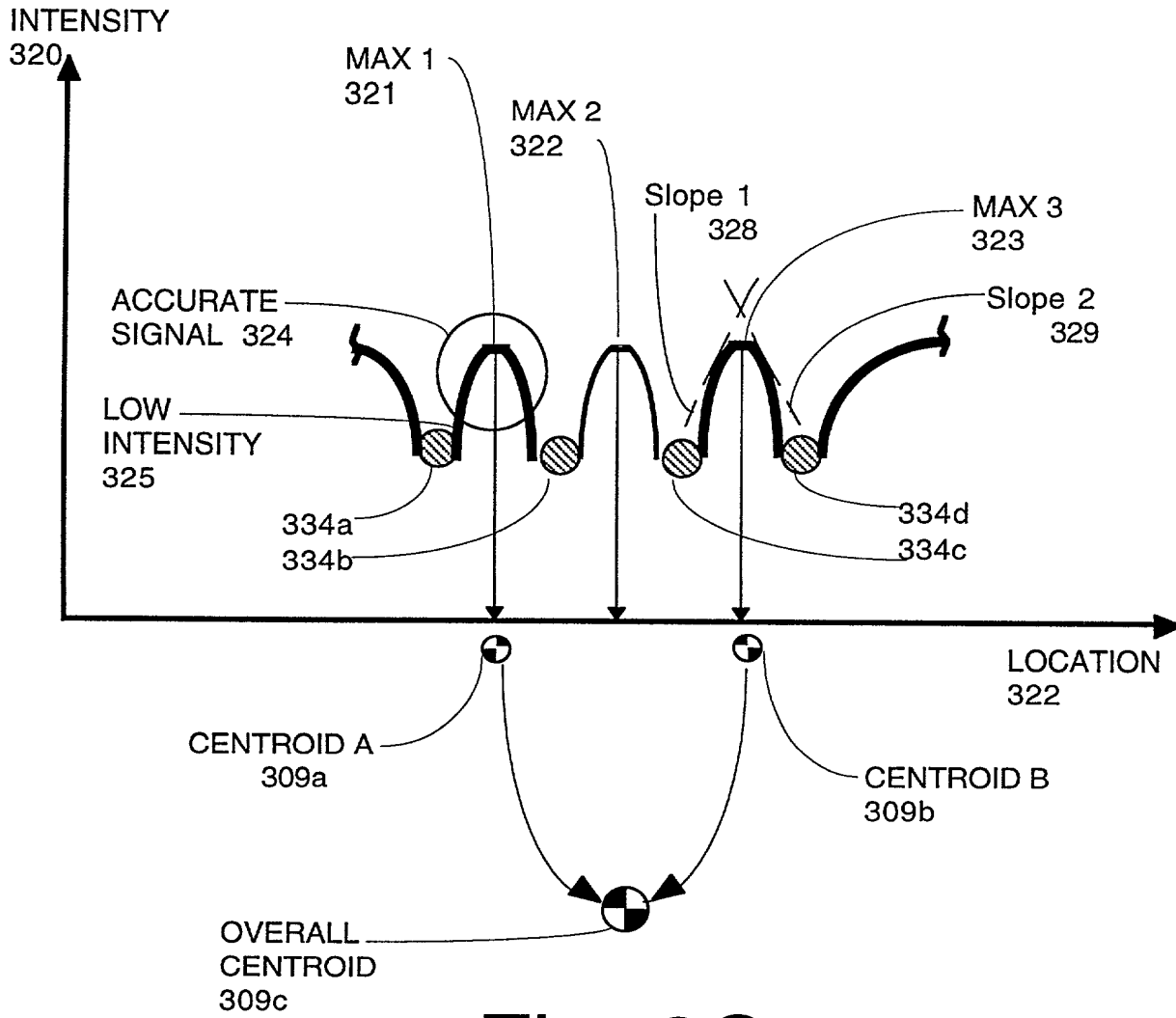
Determine a centroid of target set from extrema of return signal   4010

END

Fig. 4

Fig. 5A

Fig. 5B

548   546   500c

CMP
511 ←

542

B →   B →
540 540   540 540   538

538c ↔   ← 538a

Y
↑
└→X

Fig. 5C

302a
521   530

561
563
571   562
572   568
569
560   567
564
560   560   560
566

Z
↑
└→X

VIEW B-B
Fig. 5D

500c

INTENSITY
520

MAX 1
521

526a

526b

500e

MAX 2
522

MIN 1
530

RETURN
SIGNAL
524

524

LOCATION
522

531

CENTROID
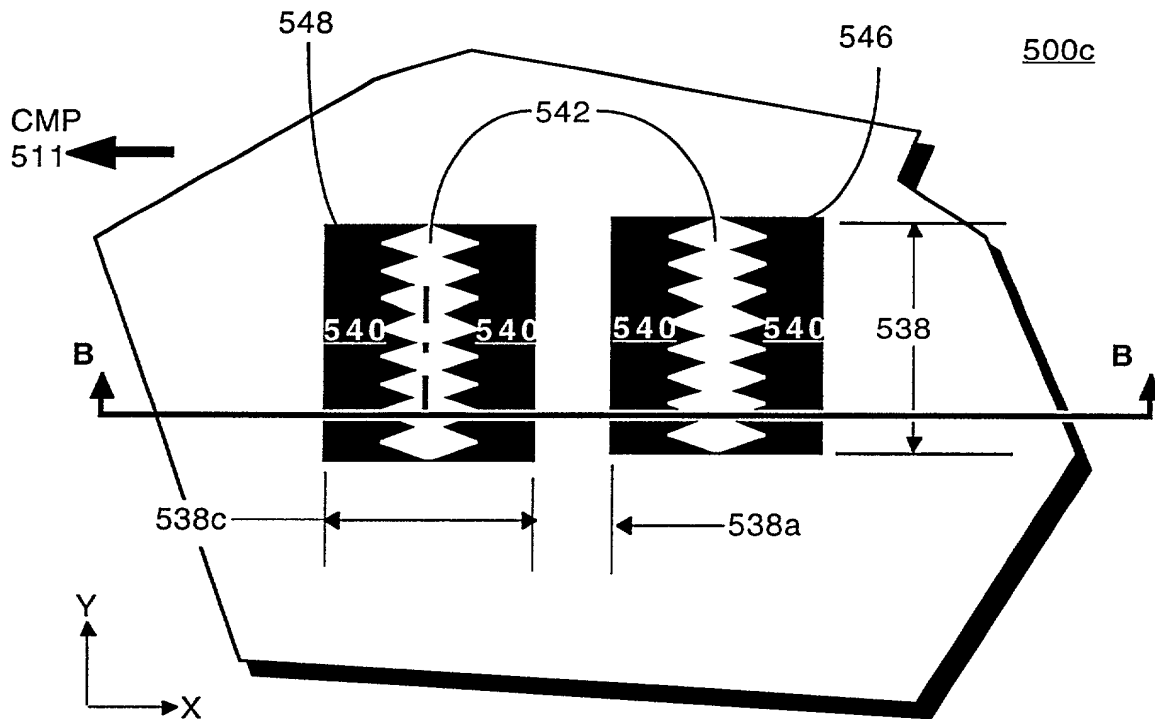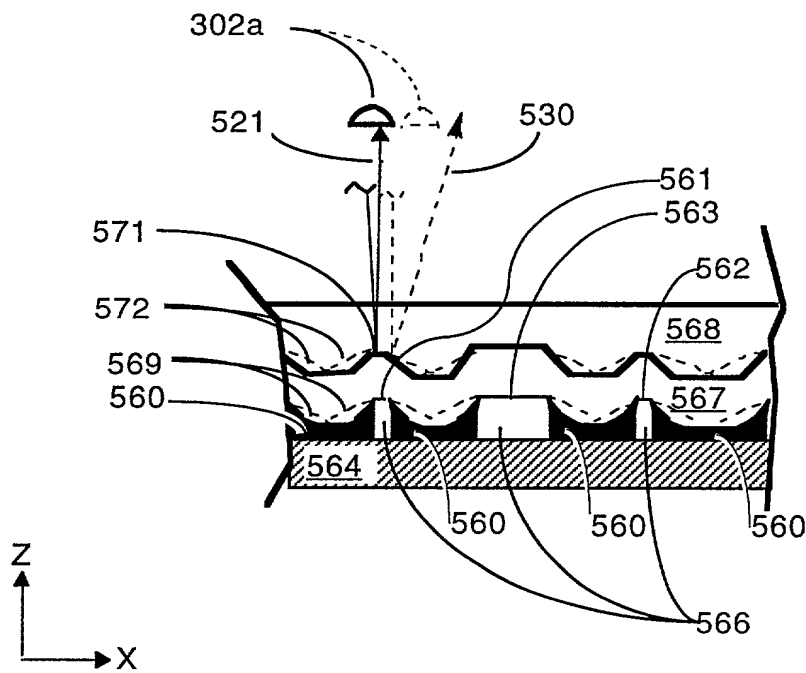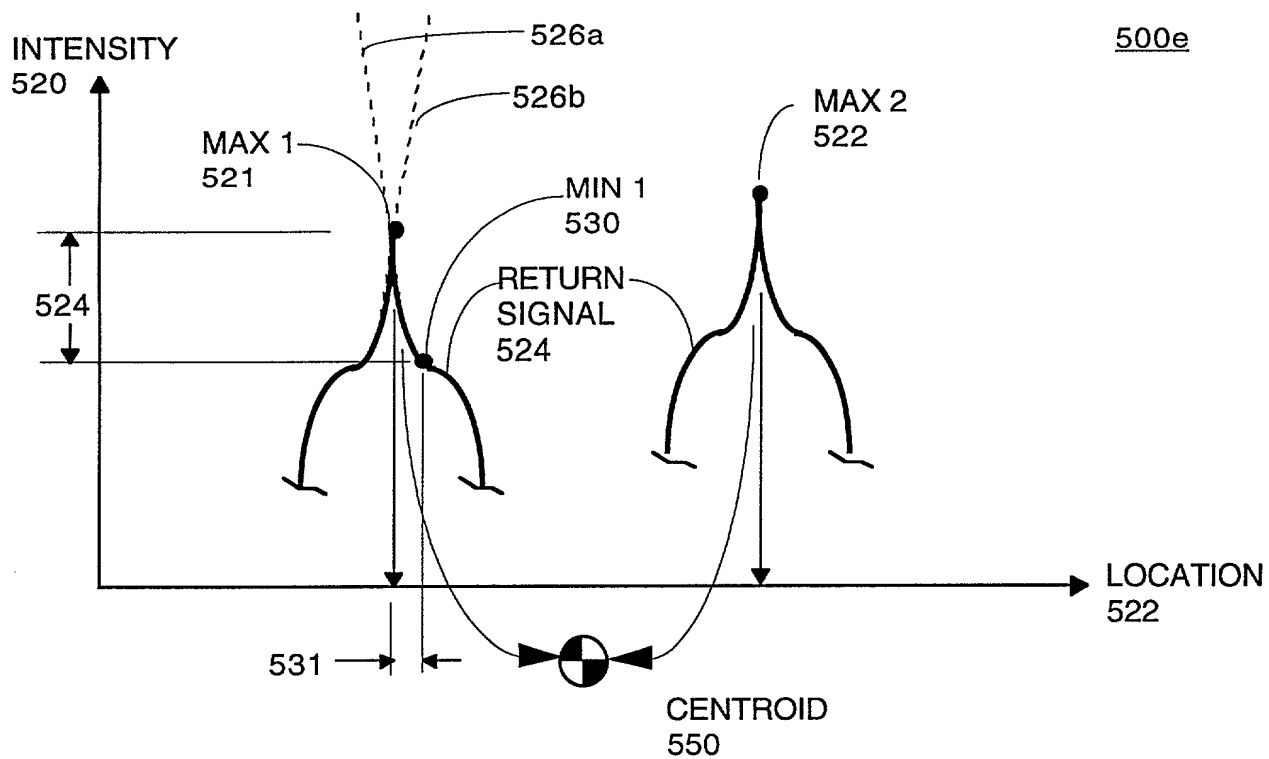550

Fig. 5E

Declaration and Power of Attorney
for a Patent Application

Declaration

As below named inventor, I hereby declare that my residence post office address, and citizenship are as stated below my name. Further, I hereby declare that I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

WAFER TARGET DESIGN AND METHOD FOR DETERMINING CENTROID OF WAFER TARGET

the specification of which:

__X__ is attached hereto, or
_____ was filed on _____ as application serial no. _____ : and
_____ was amended on _____

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment referred to above; and

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, Section 1.56(a).

Foreign Priority Claim

I hereby claim foreign priority benefits under Title 35, United States Code Section 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Number	Country	Date Filed	Priority Claimed
			_____ yes _____ no
			_____ yes _____ no

U.S. Priority Claim

I hereby claim the benefit under Title 35, United States Code, Section 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, Section 112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, Section 1.56(a) which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

Serial Number	Filing Date	Status (patented/pending/abandoned)

Power of Attorney

As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent Trademark Office connected therewith.

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Signatures

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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